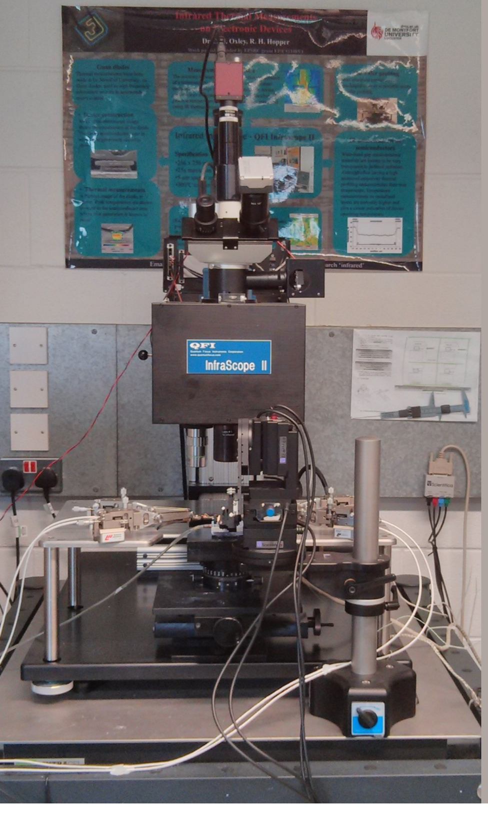

# Novel Thermal Management of Power Electronic Devices: High Power High Frequency Planar Gunn Diodes

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## Background

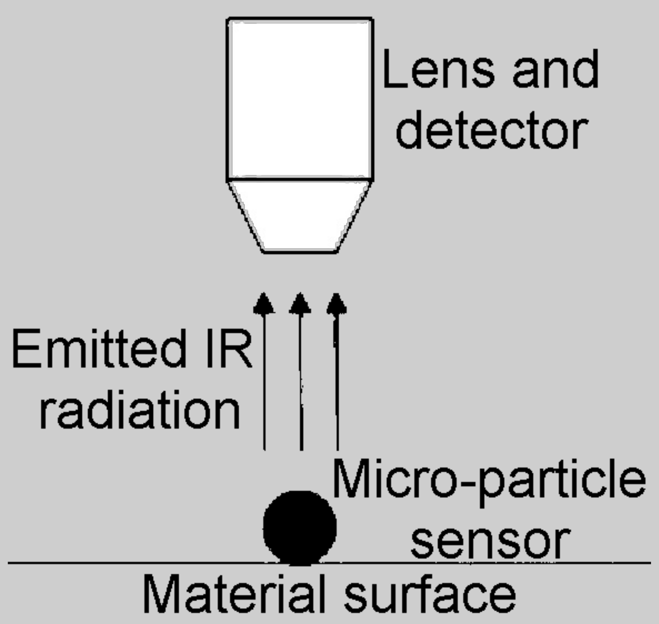
Thermal management of next generation of semiconductor devices is becoming more challenging, as the device power increases and device dimensions decrease. The work is addressing novel thermal measurement and management for planar heterostructure Gunn diodes, which will be of strategic importance for UK technology and industry.

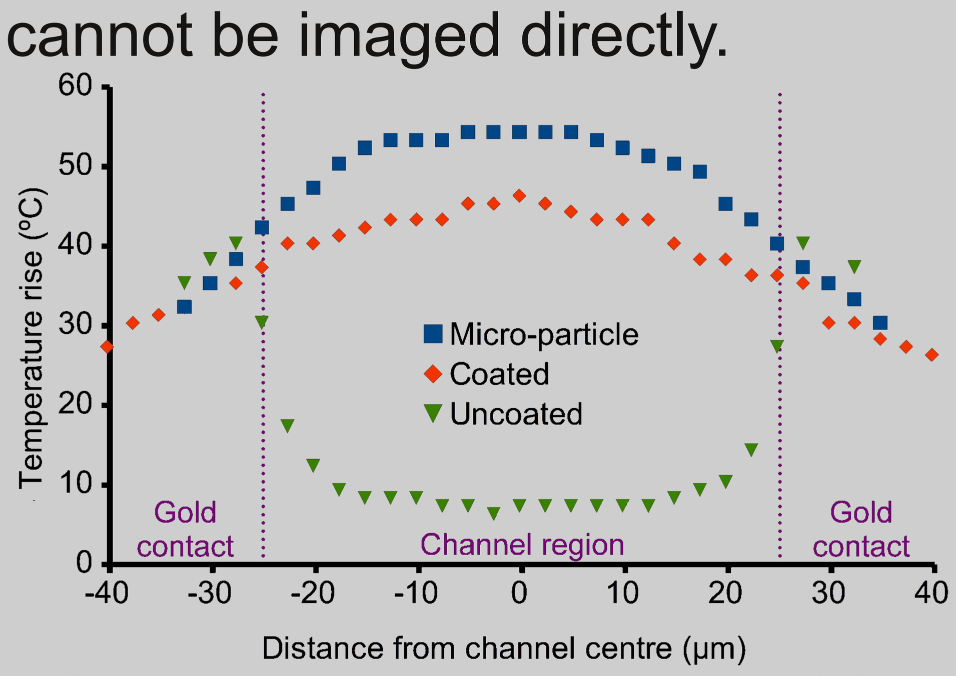
## Objective (EP/H011366/1)

Development of thermal characterisation techniques.

### IR measurement technique

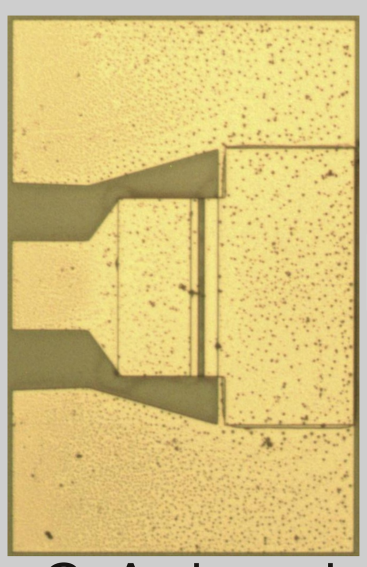
Conventional infra-red (IR) imaging can be used to make real time non-invasive 2D thermal measurements on electronic devices, in both wafer and packaged forms. However, the accuracy of the temperature measurement technique is limited when materials that are poor IR emitters (i.e.low emissivity materials) are studied. For example, gold, which is used for electrical contacts, has an emissivity <0.1 and is highly reflective of interfering background radiation. Additionally, semiconductors, like gallium arsenide (GaAs) and gallium nitride (GaN), are optically transparent and cannot be imaged directly.



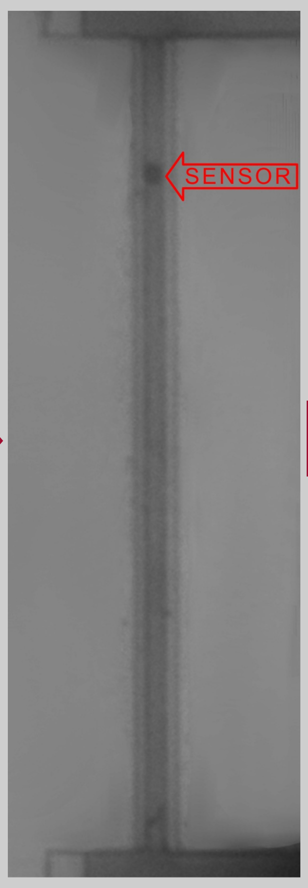



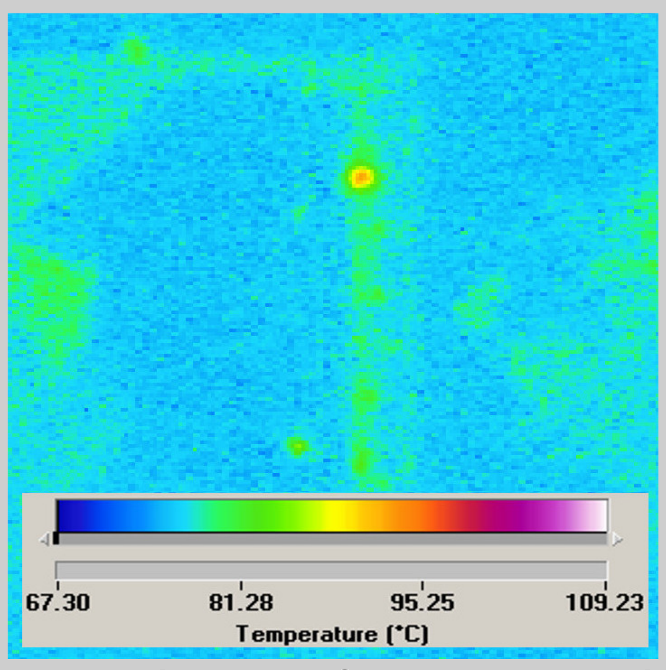

Comparison between micro-particle sensor, coated , and conventional IR measurement on a semiconductor heater structure

A novel technique has been developed to improve the accuracy of IR temperature measurements made on semiconductor devices. The technique uses high emissivity micro-particle sensor's as thermal probes. These micro-sensors can be used to obtain accurate temperature measurements on any material, including low emissivity metals and optically transparent semiconductors. This technique removes the need to coat devices with high emissivity paint, which causes heat spreading and device damage.



GaAs based planar Gunn diode

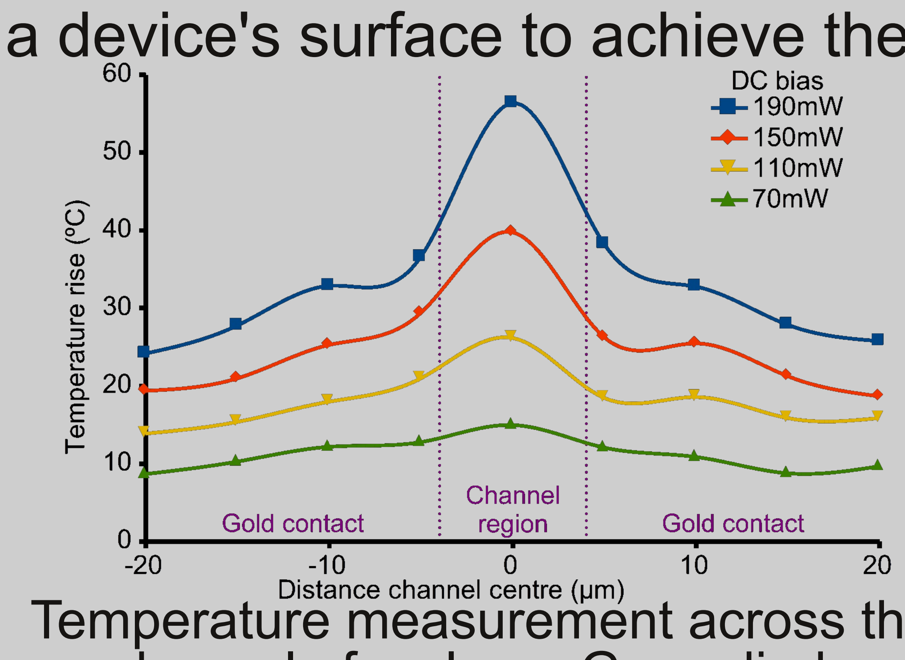


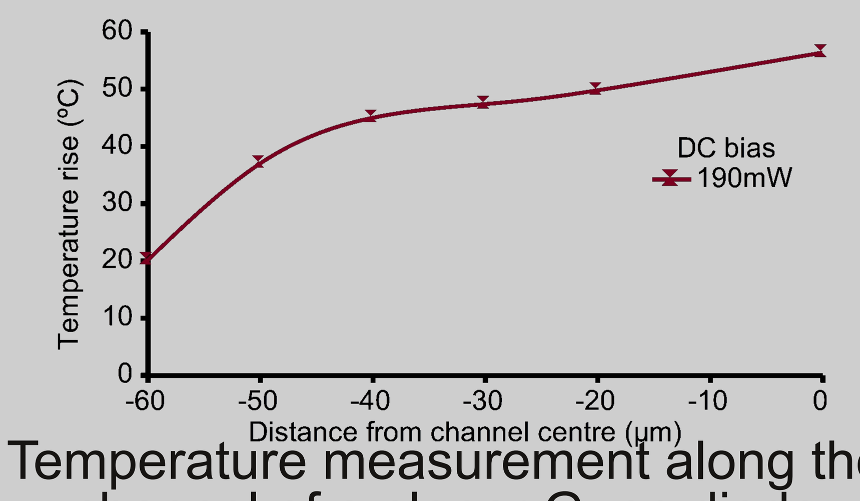

Thermal map of micro-particle sensor within the channel of a GaAs based planar Gunn diode

## Thermal measurement of planar Gunn diodes

Planar Gunn diodes have the potential as low cost terahertz sources, and have been fabricated at the University of Glasgow. The micro-particle sensor has been used to make measurements of the thermal profile along (120 microns) and across (4 microns) the channel of these Gunn diodes. The micro-sensor was positioned using a micro-manipulator and optical grid. The sensor can be manipulated to multiple locations on a device's surface to achieve the desired temperature profile.




Temperature measurement across the channel of a planar Gunn diode




Temperature measurement along the channel of a planar Gunn diode

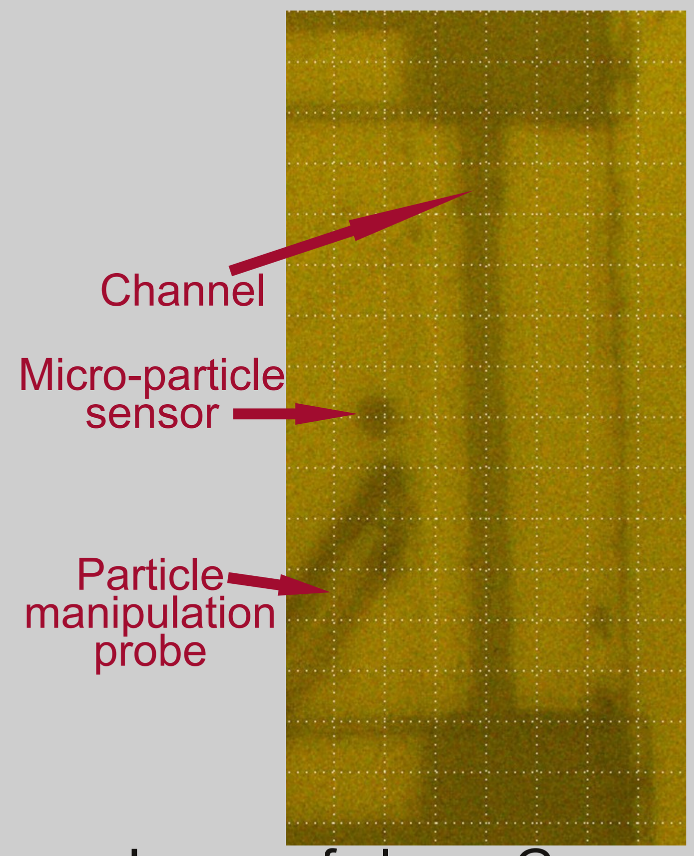
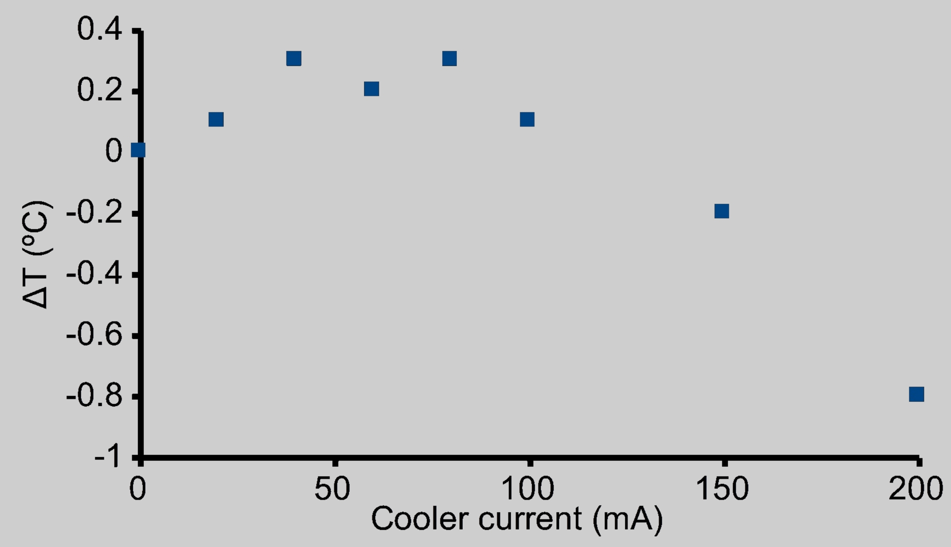


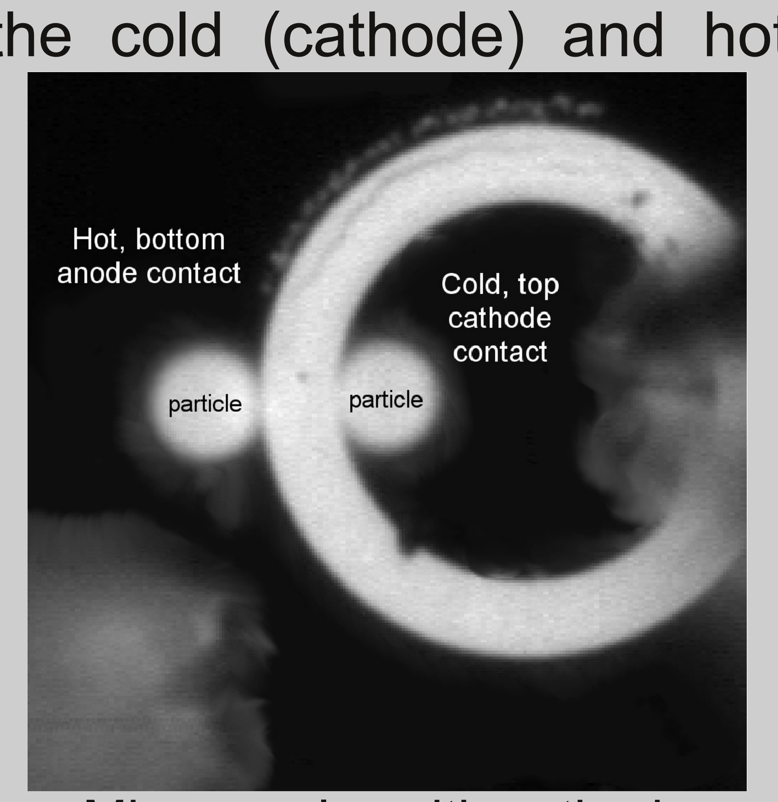

Image of planar Gunn diode with superimposed 5µm measurement grid

## GaAs based superlattice micro-coolers

To increase the efficiency of the planar Gunn diodes, integrated active, electro-thermal micro-coolers are being considered. Both Monte Carlo (University of Aberdeen) and analytical models (De Montfort University) of the micro-cooler have been developed. GaAs and indium phosphide (InP) based coolers have been fabricated with superlattice phonon blocks. Micro-particle sensors have been used to measure the relatively small temperature differences between the cold (cathode) and hot (anode) contacts.




Measured performance of an AlGaAs based superlattice micro-cooler




Micro-cooler with cathode contact bonded to external pad to thermally isolate DC probe

## Academic Partners:

University of Bristol (Lead partner) - EP/H011366/1
University of Glasgow - EP/H011862/1
University of Aberdeen - EP/H012532/1
De Montfort University - EP/H011366/1

## Industreial Partners:

CIP Technologies
Rohde and Schwarz Ltd
E2V Technologies
RFMD UK Ltd